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APPOINTMENTS VACANT

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

Norwood Technical College: teaching posts, September, 1954. 1. Senior lecturer in light current engineering. Must have good honours degree with teaching and industrial experience. Will be required to teach telecommunication subjects, and expected to carry out research. Ability to teach Television and/or Radar an advantage. 2. Assistant Grade B to teach telecommunication subjects to C. and G. Full Technological Certificate standard. Must have degree or equivalent with teaching and/or industrial experience. Burnham salary scales at present: 1. Senior lecturer £1,040 × £25 to £1,190 plus London allowance £36 or £48. 2. Assistant Grade B £490 × £25 to £765 plus London allowance £36 or £48 and graduate and training additions if applicable. Commencing salary according to age qualifications and experience.

Application forms from Secretary at College, Knight's Hill, London, S.E.27, to be returned by May 14, 1954.

The research laboratories of **The General Electric Co. Ltd.,** are proceeding shortly to fill the following important scientific and experimental grade posts.

The company hopes to appoint to scientific grade posts men of a sufficient calibre ultimately to fill the highest positions in the laboratories. Full details of promotion and salary prospects will be given to those called for interview. 1. Physicist with good honours degree for work in the field of Trunk Radio Communications. Candidates should have at least three years experience in the microwave or V.H.F. field. 2. Physicist for work in the field of communications materials. 3. Physicist to be responsible for the establishment of manufacturing techniques on special valves. Candidates must be predominantly interested in the practical aspects of such work and should be prepared to control a small regular production of these valves as required.

Candidates for these positions must have completed National Service if under 26 years of age. Apply in writing to Staff Manager (Ref. RLO/29), Research Laboratories of The General Electric Co. Ltd., East Lane, North Wembley, Middlesex, quoting 1, 2 or 3 as applicable and giving full particulars of age, qualifications and experience.

Air Ministry requires **Scientific Officer** (male) at R.A.F. station near Oxford for operational research duties in connection with aerial photography. Qualifications: First or second class honours degree, or equivalent, in mathematics or physics. Salary: within range £445 – £815. Post unestablished with possibilities of establishment through the Civil Service Commission for successful candidate whilst remaining under age 28. Opportunities for promotion to higher grade posts on staff of Scientific Adviser to Air Ministry. Application forms, quoting A313/53A from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1. Closing date May 24, 1954.

Large British Oil Company has vacancies for **Geophysicists** on its exploration staff. Candidates should have an honours degree in physics with subsidiary mathematics and/or geology, but candidates with a general degree will be considered. The work involves delineation of underground rock structure by seismic, gravitational and magnetic techniques and offers considerable scope for men with initiative who are prepared to travel and to work abroad. Normal leave is four months after two years' foreign service.

When conditions permit, facilities are afforded for married men to have their families with them on foreign tours.

Basic salary is commensurate with age and experience, commencing at £820 for young, inexperienced graduates. Appropriate allowances are paid whilst on foreign service. Generous pension scheme.

Applications quoting F.107, should be addressed to **Box 1124, c/o 191 Gresham House, E.C.2.**

North Staffordshire Technical College, Stoke-on-Trent. Principal: H. W. Webb, O.B.E., D.Sc.

A full-time laboratory technician is required for the physical laboratories to take up duties as soon as possible. Candidates should have some interest in elementary science and be able to make simple apparatus. Previous experience in a similar capacity and/or possession of an Ordinary National Certificate in Applied Physics or other qualification of a similar standard would be a considerable advantage. Salary on the scale £420 to £470 per annum for a suitably qualified candidate. Superannuated post.

Applications giving details of qualifications, training and experience should be sent to the Principal immediately.

Applications are invited for a post in the Nuclear Physics Section. Applicants must possess a good honours degree or Ph.D. in physics and must have fulfilled National Service obligations. Post-graduate research or other experience in nuclear physics is desirable. Age range 21–26 years, but candidates outside this range considered. Salary according to age, experience, and ability. Two electrostatic generators are used for fundamental research and whenever possible research results are published. Please apply in writing giving full particulars to the Personnel Officer, Research Laboratory, Associated Electrical Industries Ltd., Aldermaston Court, Aldermaston, Berks.

Woolwich Polytechnic, London, S.E.18. Principal: J. S. Tait, Ph.D.

Applications are invited from honours graduates and from students entering for their final honours (special) degree examination in June next for Research Studentships in (i) chemistry and (ii) physics. The studentship will normally lead to the Ph.D. degree (Internal) of the University of London. Its value is £350 p.a. and is tenable for two or three years.

Particulars and application form from Clerk to Governors.

THE INSTITUTE OF PHYSICS

No. 53 **BULLETIN** MAY, 1954

THE TEACHING OF OPTICS

(On March 20, 1954, a joint meeting was held in Manchester by the Manchester and District Branch of the Institute, the Institute's Education Group and the Science Masters' Association. The principal contributions, by a schoolmaster, a university lecturer and an industrialist respectively, are reproduced below).

I — By R. STONE, M.A., A.Inst.P.

(Senior Science Master, The Manchester Grammar School)

In thinking about how I would open this discussion it seemed to me that the subject could be approached in two ways : (*a*) by discussing the question of what we should teach, and (*b*) by discussing how we should teach it. Of these two approaches the first appeared to be the more fundamental : if this issue is decided satisfactorily I think the solution of the second problem will follow naturally in due course. I shall therefore speak mainly about the content of the optics syllabus. A short introductory talk leaves me insufficient time to tackle this in detail, so I shall attempt to raise one or two general issues which may provide the basis for later discussion. In this context we must realise that to discuss the optics syllabus alone is in some ways anomalous : the content of the syllabus is determined amongst other things by the time available, and this in turn is determined by the content of the syllabuses in other branches of the subject. I shall assume that the division of time between the different branches remains much as it is at the moment, though this assumption is one which you may well wish to challenge in the discussion which is to follow.

Before answering the question, "What shall we teach ?" we should ask ourselves, "What type of student are we going to teach, and with what end in view ?". In grammar schools physics is taught at sixth form level to two main types of student : (i) the future specialist—the physicist, chemist, engineer, etc., who will eventually require a high degree of competence in the subject at a high academic level, and (ii) the future non-specialist—the doctor, dentist, agricultural scientist, etc., who does not require anything like so high a standard. It has in the past been the habit, I think, to consider the requirements of these two groups at the same time, and to produce a compromise syllabus. Such a procedure is natural in as much as a compromise solution is probably necessary. In fact the two groups of students are

frequently taught in the same form, particularly in the smaller schools. But at the end of such bi-lateral discussions one is left in doubt as to how much each group has sacrificed in favour of the other. My own feeling is that the specialist group has given way very largely in favour of the non-specialist, though this is only a general impression and is not based on any inside knowledge.

I suggest that a better approach would be to discuss the requirements of each group separately, and subsequently to see how best their specific requirements can be welded into a common scheme, if it is decided that such is necessary. At the end of such deliberations one would at any rate know just how much Peter had been robbed to pay Paul. For our discussions this afternoon I think we might follow this plan and confine our attention to the specialist group, as it is in this group that the university and industrial members of the Institute will be mainly interested. Discussions of this nature, confined to the specialist group, are an urgent necessity as there has been a growing tendency in recent years to water-down academic standards—to replace genuine understanding and ability to use knowledge possessed, by requirements which demand the mere possession of knowledge. Such a policy must hamper very greatly the work in the early university years : it may well be the cause of some avoidable wastage in these years in that it allows the boy with a good memory but limited intellectual capacity to pass the advanced and scholarship papers at a relatively high standard and so pass, unjustifiably, into a university honours course. I suggest therefore that the end which we should have in view is understanding rather than knowledge.

Before passing on to specific issues I might point out that the ability to apply knowledge is a mental technique which has to be learnt, just as much as a manipulative technique : and this takes time. It is a common experience of sixth form teachers to find a boy defeated by a problem when he has all the factual knowledge and mathematical skill necessary for its solution : he cannot co-ordinate his ideas sufficiently to enable him to formulate the first line of the solution. Training in physical methods of thinking about problems should be an essential part of sixth form physics, but at present we have too little time at our disposal to devote to this aspect of our teaching.

How shall we decide what to put into the optics syllabus ? One of the attractive features of our subject from the point of view of using it as an educative medium is the way in which it hangs together as a logical whole. Whether or not a particular topic should be included might therefore depend, amongst other things, on whether or not it forms an essential part of the main trunk of the subject : if it forms only a side branch I should regard it with suspicion in the first instance. In the final outcome, of course, all the side branches are necessary to

form the unified whole, but in the early stages certain topics can be omitted without interfering with the logical development of the subject.

As an illustration of such a side branch I will quote first what I know will be a provocative issue, the topic of polarization. The whole of this topic might well be omitted at school level. I do not think that it is very vital at this stage to decide whether light is a longitudinal or transverse vibration—the reason which is commonly put forward for including polarization. In actual fact the teaching of polarization comes down, after a few rather pretty experiments, to pupils learning by heart three ways of producing polarized light and four typical uses, this being considered adequate to meet the examiner's requirements.

As a second example I might quote the defects of lenses, excluding chromatic aberration which is, I think, a special case. Students know that the paraxial laws are approximate, and that if they depart from paraxial conditions they must expect strange things to happen. Why not leave it at that and say quite simply—"This is only part of the story : it is as far as we can take it at the moment. If you go on with physics after leaving school you will learn more about what happens when paraxial conditions do not apply." If you insist on dealing with lens defects, a subject which even a good sixth form does not find at all easy, you will again, I am afraid, find students relying to a large extent on memory of facts which they have been told, with or without demonstrations.

If topics such as the above are to be omitted you will be asking yourselves, "What is to be put in their place ? " In answer to this I would suggest that nothing be put in their place in the syllabus. Let us take what is left and deal with it more thoroughly so that our students leave school understanding some physics instead of merely knowing some physics. As an illustration of what I mean here I will take a very popular experiment at A level—that of determining the refractive index of a liquid by Searle's air-cell method. This is an experiment on which I think a large number of candidates in an examination would gain 70 per cent or more marks. I would like to take a large group of such candidates and re-examine them to see how much they really understood about the optical system involved. I should ask questions such as : (*a*) would the experiment work better if a collimated beam of light were used ? (*b*) what factors affect the sharpness of the boundary ? (*c*) what effect has the thickness of the air film ? (*d*) explain why a telescopic system is used for viewing, and so on. I have a strong suspicion that the average mark on this second paper would be much less than 70 per cent, and yet the proper understanding of this experiment is far easier than the understanding of polarization : it is well within the capacity of the average sixth former. Moreover it seems to me that it is something really worth-

while. To understand how to handle a diffuse beam of light by treating it as a series of parallel beams which are subsequently brought to a focus in the focal plane of a lens so that there is a one-one correspondence between points in the plane and angles of incidence on the air-cell seems to me to be something worth striving for. It is a general technique applicable to many experiments : similar ideas are involved later in dealing with interference fringes of equal inclination.

The illustrations which I have given are, of course, only illustrations. One might decide to retain polarization but delete diffraction—or one might delete both! The point which they illustrate, is, I hope, clear. I think that at the moment we are covering too much ground too superficially. I would like to put this specific question to the university members in particular. " Would you prefer to have students coming up with a superficial knowledge of elementary work such as the air-cell experiment and also possessing a superficial knowledge of polarization, or would you prefer them to *understand* the elementary work and know nothing of polarization ? " Let us be quite honest in answering this question : as a practising teacher I say that you cannot have both—there just isn't enough time.

I might point out on this question of time that many university lecturers in estimating what a grammar school pupil should be able to absorb in the sixth form think of him in terms of the relatively mature product who comes up to them at the age of 18 after spending three years in the sixth form. Please remember that when we first get him he is only 15 years of age and has just passed the ordinary level : we must go very slowly in the early stages. For reasons which will, I think be clear, the bulk of geometrical optics is done in the early stages of the sixth form course. An understanding of the optical system of the air-cell experiment is quite possible even at this early stage, as I have said, but you cannot do it in five minutes—something more like half an hour is required followed by suitable practical work.

In the field of physical optics the same dichotomy presents itself—a little well done or a quick skate over a wide field : a little interference plus a little diffraction or a genuine understanding of a wider field of interference phenomena and no diffraction. Again, for the specialist, I would come down on the side of depth rather than breadth. Having understood the principles of Young's experiment and performed it in the laboratory there is considerable value in going on to discuss other ways by which two coherent sources may be obtained, and various uses to which the system can be put. In the case of thin film interference, problems of localization of the fringes, of the effect of silvering, the conditions necessary for interference both with white and monochromatic light, and with diffuse and collimated beams can be discussed satisfactorily, though some of these features might be restricted

to scholarship rather than advanced level. Fringes of equal inclination might be introduced as well as contour fringes. Instead of such a course we have at the moment—I summarize briefly the present N.U.J.M.B. syllabus—(*a*) twin source interference restricted to Young's slits, (*b*) thin film interference restricted mainly to a simple treatment of contour fringes in white and monochromatic light, (*c*) the diffraction grating, (*d*) diffraction at a straight edge treated solely by demonstration and ex-cathedra statements, leading to resolving power similarly treated, and (*e*) the crystal as a grating for X-rays. There is considerable support amongst educationalists for the general thesis that depth in study is a more valuable feature than breadth. I wish to stress that the advantage to be gained from a full study of interference, say, is not that one finishes the course knowing ten more things about the topic, but that by studying interference in a variety of contexts the physical principles involved become clearer and more familiar and more thoroughly assimilated.

Before concluding I must, I think, raise one or two points which might be discussed in connection with the second approach which I mentioned at the outset—namely, how we teach.

The main prop on which all school optics stands is, of course, the treatment of geometrical optics : the paraxial laws for lenses and mirrors. In so far as we have difficulties at the sixth form level in this matter they are due, I think, to too early an introduction of algebraical methods. Introduced at too early a stage the paraxial formulae tend to be treated as exercises in calculation without the necessary consciousness of the physical background. This state of affairs can be remedied in junior forms by the combined effect of more practical work with more geometrical construction work. As far as I can find it is unusual, for instance, to do an experiment to find pairs of conjugate points for a convext lens and so determine a series of values of f until the paraxial formula has been introduced. Provided one is careful in guiding the students so that they do not take values of u which differ greatly from $2f$ the results of such an experiment can be evaluated graphically with a precision which is quite adequate at this stage. The boys enjoy doing the diagrams and with a little encouragement will take enormous pains with their work. In this they learn a great deal about the behaviour of the lens, and also gain valuable experience in careful and accurate graphical work which will stand them in good stead later on. In the same way they can tackle numerous problems by graphical methods, and really understand what they are doing in the process, whereas the physics will be lost to them after the first line of an algebraical solution. As an example such a problem as—given the magnification and the distance between object and screen for a convex lens, find the position and focal length of the lens—can be solved

quite elegantly by graphical means. Perhaps we resort to the algebraic formula too soon because it admits of quicker and more accurate solutions in examinations. The examiners at Ordinary level might do a great service to the teaching of optics in schools if they refused to accept anything but geometrical solutions at this stage.

II—By H. G. KUHN, M.A., D.Phil., F.R.S.
(*Clarendon Laboratory, Oxford*)

This discussion is concerned with what to teach in optics rather than how to teach it ; but these two questions cannot be entirely separated. Certain matters should only be taught if they can be taught properly, i.e. if the available time, the intelligence and the previous training of the pupil allow an adequate treatment. The university teacher will hardly mind if the freshman knows nothing of even an important branch of the subject, perhaps polarization or the theory of diffraction. His most desperate task is the teaching of the pupil who thinks he knows the matter, because he has learnt some formulae, and who has lost the freshness of approach to the subject.

Some problems in the teaching of optics arise from the peculiar nature of this branch of physics, its close connection with the most important of our senses. Direct observations and measurements which form the basis of all science can be learnt and practised in optics more easily than in other branches of physics, and they should be accordingly stressed. In proceeding from the observed facts to their interpretation, one meets, unfortunately, great difficulties at the early stages because one is dealing with a wave motion whose wavelenth is neither negligibly small nor extremely large. As a result, some mathematically tractable but physically unimportant aspects are apt to be taught and made the subjects of examinations.

The unhappy conflict between the requirements of entrance and scholarship examinations on the one hand and the need for teaching really useful physics on the other hand unavoidably enters into any discussion on what should be taught in school. My suggestions refer to what appears to me useful as an introduction to physics ; the compromise with the requirements of any particular examination has to be made by the science master himself.

In geometrical optics, there is first the question of rays versus wave surfaces. In my opinion, the pupil should get used to thinking of wave surfaces as the physical reality and of rays as normals to the latter, generally indicating the direction in which the energy is flowing. The pinhole camera in which the definition of the image first improves and then deteriorates with decreasing hole size is a good illustration of the fundamental fact that wave surfaces or rays are useful concepts only as long as the wave is not laterally restricted too much. Once

this has been made clear, I can see no harm in the use of rays for the construction of images, because they are easier to handle and to draw than wave surfaces. On the other hand, phenomena involving continuous variation of the refractive index, such as atmospheric refraction, are much easier to treat by means of wave surfaces ; and Snell's law, explained with the use of Huygen's construction, fits easily into this picture.

In the treatment of optical image formation, the conditions under which an image is formed, e.g. restrictions of angles, should be stressed more, and the relations between distances of objects and images less. Practice in handling the formulae is, however, useful as a mathematical exercise and, alas, most necessary for examinations.

Strangely neglected are telescopic systems and images at infinity, though both are most important in practice. The difficulty of drawing images at infinity appears to have made them unpopular with text-book writers. The virtual image formed by the eye-piece of a telescope is sometimes described as being at infinity, but that formed by the eyepiece of a microscope is almost invariably supposed to be at a finite distance, and equally that formed by an ordinary magnifying glass. Very few of our freshmen are able to focus the crosswire of an eyepiece for infinity. The fact that the optical instrument in a Pulfrich refractometer is a telescope, focused for infinity, comes as a surprise to most undergraduates, even after they have carried out measurements with it. It would seem most useful if schoolboys were taught to set up telescopes with spectacle lenses or to measure the size of the image of the sun or the moon.

For the teaching of interference, it is very unfortunate that the phenomenon easiest to show is one most difficult to explain : Newton's rings. Nearly always the pupil is taught to swallow a purely formal explanation, ignoring the essentials but, naturally, leading to the required formula. Any proper explanation of interferences of equal thickness will almost certainly have to start from fringes of equal inclination whose explanation is straightforward. Calculation or direct observation shows that these fringes become wider with decreasing distance between the surfaces, i.e. the interference condition becomes progressively less sensitive to the angle. With the effective elimination of the angle from the interference condition for small distances, it becomes possible to use the distance as variable by tilting one surface and focusing the eye on the surface. With quite inexpensive equipment it is possible to demonstrate every step of this argument by experiments.

Interferences in divergent light, of the type of Young's double slit fringes, present less difficulty. They should certainly be treated and demonstrated. The requirement of a primary slit, to form a well-defined wave front, is often not sufficiently stressed.

The last-mentioned experiment involves diffraction, but only in a qualitative way ; the formation of a spherical wave by a pin-hole is plausible enough. But for any quantitative treatment of diffraction phenomena, Huygens' principle in the more general form due to Fresnel has to be introduced. If this is done at all, it should be stressed that the principle is neither obvious nor can it be derived in an elementary way ; it has to be considered as a working hypothesis. Much harm is done, in my opinion, by superficial, glib " derivations " of formulae of diffraction. In the diffraction grating, every schoolboy will draw these parallel lines leaving the slits of the grating at an angle. Are they rays ? Are they even normals to wave-fronts ? Does the mere fulfilment of the interference condition explain the essence of the action of the grating, namely the formation of sharp spectral lines ? These matters cannot be explained in an elementary way and one should carefully avoid the impression that they are, and also stress the fact that real gratings do not consist of slits, anyway.

Owing to restriction of time, I have confined myself to a few matters of special importance and special difficulty. Other topics which should certainly be taught are photometry (excluding brightness of images), body colour and surface colour, the human eye, the rainbow, measurement of the speed of light and the elementary facts of polarization. The existence and importance of lens aberrations should be stressed, but only chromatic aberration need be treated quantitatively.

The main consideration which should govern the choice of syllabus is this : we should offer explanations and theories only if they are genuine ; they need not be rigorous, but must contain the essence. A mere formal mathematical treatment whose physical idea is beyond the pupil's grasp not only will do no good but positive harm in that it will teach the boy to learn without questioning.

III — By E. W. H. SELWYN, B.Sc., A.R.C.S., D.I.C., F.Inst.P.
(*Assistant Superintendent, Research Laboratory, Kodak Ltd.*)

In considering what should be taught in optics it is important to realize that the subject is highly artificial in the sense that what we know about it is the result of those artefacts called experiments. Consequently we must first ask whether pupils are to be treated as ordinary human beings, who might want to know why the stream they are paddling in looks less deep than it is, why their shadows walk along with them, where the rainbow comes from or why they can see a little upside-down picture of the garden in a dew-drop on a spider's web, or as immature physicists. The answer, no doubt, is that they start as ordinary boys and girls who pay the appropriate penalty for asking such questions, by becoming physicists, to some extent, in some cases. An adequate answer to the above questions and others like them can be

based on the supposition that light travels in thin straight pencils, and this is probably the best way to begin the study of optics. But it is as well to recognize that the supposition can lead only to an approximate description of optical phenomena. When, however, they ask why a film of oil on a wet road glistens with pretty colours, why the sky is blue, or why they must use a very expensive lens on a microscope instead of a simple lens very much stopped down, then it is high time to begin talking about waves. There seems to be no common natural phenomenon which forces the idea of waves on the observer. But by the time it is necessary to think about waves the subject will have become very much a laboratory study and a laboratory demonstration that a wave theory is inevitable will be, in consequence, less objectionable than it would be at the beginning of the study of optics. Young's double slit interference experiment is unquestionably the best way of introducing the idea of waves in optics, for the wave theory is almost a direct consequence of it. Consider the light coming from the two slits towards one of the dark bands nearest the bright central fringe. If the light from one slit is carrying something which we call Q through the dark band at some particular instant, then at that same instant the light from the other slit is carrying $-Q$ through the dark band. This is possible because the distances of the two slits from the dark band are different and a little consideration soon shows that the light must carry along with itself a sequence of values of Q in the order $+Q\ -Q\ +Q\ -Q\ +Q\ \ldots\ldots$

Of course, everyone agrees that the wave-theory must be introduced into school optics. The question that requires an answer is whether having once introduced it the further development of the subject should be based exclusively, or nearly exclusively, on it. I am sure that the answer is, "Yes." There are several reasons for this. In the first place the subject becomes homogeneous. The theory of optical instruments, interference, diffraction and birefringence become different aspects of the same fundamental phenomenon and not discrete subjects separated by different mathematical techniques. At a later stage optics ties up with electromagnetic theory, with X-ray crystallography, and with spectroscopy. It becomes, in fact, a respectable element of modern physics. Also, the theory of optical instruments is easier to understand by wave theory. It is true that here and there it is convenient to use the idea of rays, but if these are regarded as normals to the wave-surface, the objections associated with the primitive notion of rays as thin pencils of light lose their force. Now it could be objected that advanced studies of the theory of optical instruments, of the sort required by optical designers, use the idea of rays almost exclusively, and that a student not well acquainted with the handling of ray calculations would be handicapped in such studies. The reply to such an

objection is that the number of optical instrument designers in the country can never be sufficient to warrant forcing their special methods on all students. What is wanted by students is a sufficient understanding of optical instruments to be able to select and use them intelligently and to avoid attempting the impossible on those occasions when they may need to make, or get made, optical devices in connection with their work.

It would be helpful in this respect if, in dealing with the standard lens formulae (like $1/u + 1/v = 1/f$), it were pointed out that the wave-surface after refraction can be represented by a series of terms, the first and most important of which represents a spherical wave-surface, the others being in the nature of modifications of the first term. It is to this first term that the standard lens formulae apply. The first term can be calculated by supposing the object and image and lens aperture to be confined to the threadlike " paraxial " region round the axis, but if it happens that the lens is well corrected the " paraxial " formulae are very good approximations for big lenses and wide fields. This approach leads to the consideration of the Seidel aberrations. These are showing signs of appearing in relatively elementary textbooks, even in school books. The idea behind introducing them, namely, to show how optical instruments depart from perfection, is sound and proper. But unless the treatment is purely descriptive (a process leading maybe to knowledge, but not education) the ray-theory mathematics can hardly be described by another word than turgid. The wave-theory of the Seidel aberrations, by comparison, is simple and elegant.

Now in all this treatment by wave-theory, Huygens' Principle is essential. It is well-known that the exact mathematical treatment of it is difficult. Nevertheless it can be understood without formal mathematics in the following way.

The only case with physical reality where we can properly assume that we know what happens is that of an infinitesimally small light source sending out light symmetrically into empty space : the infinite plane wave is a fiction. Assume that at some particular instant the spherical shell produced by the source flickering on and off is replaced by a close-packed set of sources of light. Then at any given instant, there will be produced a sequence of effects all along any line through the original source between the greatest limits to which light can reach at that instant. The right answer can only be got by supposing that the sources replacing the original shell consist of two : a positive source and behind it a similar negative source. In the limit they must be vanishingly close together and infinitely strong. Such a doublet source produces a positive forward pulse and a negative backward one. If to this type of source is added a simple source producing a positive

pulse in all directions round itself, the condition that there is no back-wave can be met. Also it is not difficult to see that the amplitude in a direction to θ the forward direction could well be represented by $1 + \cos \theta$.

The division of a complete spherical wave into Fresnel zones (or better, into infinitesimal zones) can then be used to show that Huygens' Principle does give the right answer. If the same argument is tried with a plane wave there is trouble out at infinity—which is only right and proper, this being what comes of starting with a physical impossibility.

Up to this point we are sure what we are doing. In the use of Huygens' Principle we assume that we can replace a bit of the complete wave (the only bit, in fact, that comes through some aperture like the aperture of a lens or a slit in the idealized gratings of the text-books) by a set of light sources. Having by this means calculated what result is expected the answer must be checked by experiment before we have the necessary confidence to do the same thing again in other circumstances. This is where the circular aperture, the circular obstacle and so on come in.

One of the great advantages of wave theory is that it leads quite naturally to a consideration of the sort of image to be expected when the wave-surface emerging from a lens is exactly spherical. Text-books sometimes fight shy of the calculation of the diffraction image because it normally involves Bessel functions. The difficulty can, however, be dodged. It is by no means difficult to show that the image consists of a bright central disk surrounded by alternately dark and bright rings, and also, with a little more trouble, to estimate quite accurately the size of the image. Moreover an even simpler calculation allows an estimate to be made of the depth of focus, and the departure from spherical permissible in the wave-surface before the image deteriorates seriously. Anyone who has used a microscope knows the importance of these considerations.

When dealing with instruments it is important to emphasize that the function of component lenses is to form images. Anybody will accept the proposition that having got one image, for example that formed by the objective of a telescope, it is theoretically possible to form another image of the image, for example by the eyepiece of a telescope. The problem then is whether the light from the objective can get into the eyepiece and then into the observer's eye. This problem is solved, in principle, when it is realized that the eyepiece also forms an image of the objective. In other words the eyepiece is not only a magnifier but also a field lens.

Now it will be thought by many teachers that the foregoing comments apply at a more advanced level than can be dealt with at

schools. Except for pupils at scholarship level this is true. The intention of them, however, is not to attempt to lay down a syllabus—that is the function of teachers and examiners acting in disagreement—but to show that an exposition of optics is possible which involves no sudden changes in approach, no arbitrary division into subjects.

As this is an occasion for expressing personal opinions may I make two further points ? Although much of my work has been in optics, I cannot remember an occasion when I have made use of any sign convention, except for occasional ray-tracing. I know that there are things called planes of unit magnification and nodal points, but little more than that about them. There seem to have been no difficulties in consequence of these personal peculiarities. This satisfactory state of affairs I attribute to the fact that I have not had to pass examinations for a long time.

REVIEWS OF BOOKS

A Laboratory Manual of Experiments in Physics. By L. R. INGERSOLL, M. J. MARTIN and T. A. ROUSE. (New York : McGraw-Hill Co. Inc., 1953). Pp. xi+286. Price 32s.

This is the sixth edition of a book which first appeared in America in 1925. It must therefore have enjoyed considerable success in American schools and universities. Yet, as far as the reviewer is aware, it is little used in Britain. This is probably due, firstly, to some differences in content of sixth form and first year university courses in experimental physics in this country compared with those prevailing in America, secondly to references in the text to equipment manufactured in the U.S.A. where the counterpart is not always easily available here, and, finally, to the price of the book which, though reasonable for a well-produced volume, is yet somewhat higher than that of similar works published in England. Yet it is a pity that our laboratory courses in introductory experimental physics do not make more use of this excellent work.

Especially praiseworthy features are the clear instructions about the relevant theory and practice concerned with each experiment, including details of manipulations, precautions and observations often lacking from similar texts. Simple but important ideas about errors are included. Here the policy has not been, as is sometimes found, to write about the theory of errors in the first section of the book and then hardly mention this theory again in the rest of the text ; rather sources of error in practice are discussed in all stages of the work. Further, each experiment is followed by a series of questions designed to ensure that the student has understood not only the experiment but also its implications and, where possible, its relation to everyday observations of natural phenomena.

In places the instructions given are somewhat pedantic ; for example, it seems unnecessary to enlarge the text by data on how to write up the experiments, or with statements such as " With the consent of the instructor, the student may experiment . . .", and again, " One experimenter then begins to turn the handwheel while the other adjusts the weights." Too often this sort of statement occurs ; after all, if the student is so dull as to require such guidance, he had best give up physics anyway ! However, one must forgive occasional over-enthusiasm in this direction on the part of the authors, especially in view of the general excellence of the many details given to ensure that the experiments are carried out as correctly as possible.

Most of the experiments follow the pattern familiar in laboratory courses in Britain. Especial mention should be made, however, of some which are either novel or have novel features ; examples are the experiments on the composition and resolution of forces, aerodynamic forces, the inertia balance, power refrigeration and the heat pump, acoustics of auditoriums, the eye as an optical instrument, optical density, equipotential surfaces.

A student who during, say, a two-year course, had the opportunity of undertaking many of the experiments described in this book would not only become well-trained but would also find the work interesting and stimulating.

J. YARWOOD.

Nuclear Physics. By W. HEISENBERG. (London : Methuen and Co. Ltd.). Price 12s. 6d.

This book is based on a series of lectures which the author gave to the Association of German Electrical Engineers. The present book is a translation of the 1948 edition and aims at making the main theoretical conceptions of nuclear physics intelligible to readers who are broadly familiar with physical principles. As might be expected from Professor Heisenberg, the selection and presentation of the main topics are excellent, and even quite difficult ideas, like the conception of an *exchange force*, are made to appear simple. The reader unfamiliar with nuclear physics is led by easy stages through three chapters which introduce him to the main facts about atoms, molecules, and radio-activity, to a consideration of the normal states of atomic nuclei, nuclear forces, and finally to nuclear reactions. There is a good section on the stability of nuclei and nuclear types. The final chapters give a simple account of the tools of the trade, the instruments and the great machines, and the practical applications of nuclear physics. Professor Heisenberg has some well-chosen examples of the use of radioactive tracers; one was interested to read that the permeability of the rubber of a gas mask to poison gas can be measured by the tracer technique.

The subject of nuclear physics is developing so rapidly that even an elementary book needs to be kept constantly under review. The decision not to revise the book after 1948 has proved unfortunate, for from 1947 to the present time there have been immense advances on the technical and theoretical sides of the subject. New techniques and the skilful use of older techniques have led to discoveries of great importance on the various sorts of unstable particles, the π-mesons, the τ-meson, the θ^0-meson, and the hyperon, and their rôle in nuclear structure. This subject is barely mentioned by Professor Heisenberg, nor is the very fertile idea of the shell model of the nucleus. Again, in the section on techniques, the account of the Geiger counter is badly out-of-date, the impression being given that a self-quenching counter is used with an external resistance of $10^{10}\Omega$ (Fig. 31, p. 144).

The translation is, on the whole, excellent, and the book is very easy to read. A few corrections may be noted. The π-meson is not a "heavy" meson (pp. 56 and 102), nor is it produced in nuclear fission (p. 102). A small c should be used throughout p. 72 ; the word "one" is omitted before "isotope" on p. 112. Finally, there is a delightful misprint in Table Ic, p. 205, where the antineutrino is called the *artineutrino* !

G. D. Rochester.

Physics. Principles and Applications. By H. Margenau, W. W. Watson, and C. G. Montgomery. (New York : McGraw-Hill Book Co. Inc.). Second Edition. Price $7.50. (53s. 6d.)

The title describes this book accurately. It is not a textbook adapted to any particular examination level, but a thorough exposition of physical principles reinforced by examples of their application. The exercises provided would be suitable for sixth-form boys ; the text itself is for readers with a rather more mature outlook. It should serve its purpose, which is to give prospective engineers a grounding in physics, very effectively. The appearance of a second edition four years after the first suggests that its merits have already won appreciation.

The first fifteen chapters—nearly one-third of the book—deal with mechanical principles, and the explanation and examples here are excellent. The section on heat is slender, but includes a useful introduction to heat engines and a chapter on meteorology. The main revision has been in the section on electromagnetism, which is treated as before in an appropriately modern way. Recent technical devices ("trons" of various "megages," and the like) are mentioned as illustrations of elementary principles rather than as impressive capital investments, which is refreshing. Units, say the authors, are the plague of every student of physics ; the immunization prescribed

seems almost as uncomfortable as the disease itself, for their very sound and logical treatment of units does not make easy reading. But it should encourage the student to use his understanding rather than his memory, and is to be commended. This outlook is characteristic of the book as a whole, and the reader who is prepared to master the more exacting parts will be well rewarded. He will be helped considerably by the clear and attractive style in which it is written.

G. R. NOAKES.

NOTES AND NOTICES

The Ballot for the Board

Corporate Members in this country will have received the ballot paper for filling the vacancies about to occur for President, and other members of the Board. They may have wondered why a ballot paper is necessary in a non-contested election and why there is no choice of candidates. The answer to the first question is that, according to legal opinion, Article 50 of the Institute's constitution requires this even for a non-contested election. It is, however, intended to propose modifications to this and several other Articles and By-Laws at the first convenient opportunity ; many of them are out-of-date and a start has been made on a thorough-going revision. The answer to the second question is that a contest has already, to some extent, taken place. The Committees of the home Branches and of the Groups are invited to suggest names for seats on the Board and so also are members of the Board. This year nine names were suggested for two vacancies. The Board's nominees are selected from this list by ballot, and in making their choice members of the Board are asked to bear in mind the balance on the Board as between branches of physics, geographical areas represented, and academic, industrial, and government employment. The suggestions for nominations for President and officers are made in the first place by a small committee consisting of the President and two immediate Past Presidents ; the Board is not bound to accept these suggestions but normally does so.

Members are given an opportunity to put up candidates in opposition to the Board's nominations and in the event of such nominations there must be a contested ballot between the Board's nominees selected as described above and the members' nominees. The fact that the Board's nominees have been accepted now for many years is taken to mean that on the whole members are satisfied with its conduct of the Institute's affairs, and perhaps that members recognize that the Institute is fortunate to have the active services of so many busy people.

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Institute of Cancer Research : Royal Cancer Hospital, Fulham Road, London, S.W.3. Junior physicist required to assist in physical and clinical work with radioactive isotopes. Commencing salary £565 per annum. Applications, giving the names of three persons to whom reference can be made, must be received by the Secretary not later than May 22.

Institute of Cancer Research : Royal Cancer Hospital, Fulham Road, London, S.W.3. Junior Physicist required, preferably with medical physics experience, to assist in physical studies in relation to radiation therapy Commencing salary £565 per annum. Applications, giving the names of three persons to whom reference can be made, must be received by the Secretary, not later than May 22.

Metallurgical society requires **editorial assistant** to edit scientific papers and abstracts. A degree in metallurgy, physics or chemistry and some knowledge of languages essential. Salary up to £600 p.a., according to qualifications and experience. Superannuation scheme.

Physicists required for a laboratory situated in Northamptonshire to work on properties connected with semi-conductors, ferro-magnetics, ferroelectrics, electronics crystal growing and dielectric materials at high frequency. Salary will depend on qualifications and experience. Box A.V.59, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

Physicists and **chemists** required for research in the field of semi-conductors including photo-cell development and study of intermetallic compounds. Men of Ph.D. standing, or graduates with some relevant research experience preferred. Location Northamptonshire. Box A.V.60, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

Physicist required to create and lead a group for research and development on the control and instrumentation of atomic energy plants and allied subjects. Experience in nuclear physics desirable. Apply giving particulars of education and experience to **Personnel Officer, Elliott Bros. (London) Ltd., Elstree Way, Borehamwood, Herts,** quoting ref. 466.

Department of Scientific and Industrial Research require unestablished **Scientific Officer** (physicist) at Water Pollution Research Laboratory, Stevenage, for research on physical problems arising in the study of polluted rivers. 1st or 2nd class honours degree in physics with mathematics as subsidiary subject, or equivalent qualification. Inclusive annual remuneration for a 45½ hour week ; £458 - £839 (men), £468 - £741 (women). Prospect of establishment for applicants under 28. Favourable housing facilities for married staff. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A85/54A. Closing date May 24, 1954.

Electronic test engineers and **calibrators.** Staff appointment and generous bonus scheme. Apply to Dawe Instruments, Harlequin Avenue, Great West Road, Brentford.

Ilford Limited require a graduate in physics to undertake investigations at Brentwood into testing methods. Previous experience in research work is not essential. Salary according to age and experience. Apply in writing to Research Director, Ilford Limited, Ilford, Essex.

Rhodes University, Grahamstown, South Africa.

Applications are invited for the post of **senior lecturer in physics,** from January, 1955.

The salary scale is £1,050 × £50 – £1,400 p.a. plus, in the case of married persons only, a variable cost-of-living allowance, at present £234 p.a.

Previous experience and academic qualifications may be taken into account in fixing the commencing salary.

Full particulars and application forms may be obtained from the Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in South Africa and London, is July 1, 1954.

A vacancy exists for a graduate in physics or chemistry involving fundamental work on special ceramic materials with particular reference to the relationship of structure to electrical and mechanical properties. The vacancy is in the Senior Scientific Officer grade (salary range £675 – £1,025) ; the post is permanent and carries superannuation under F.S.S.U. Applications, giving full details of age, qualifications and experience to the **Director of Research, British Ceramic Research Association, Queens Road, Penkhull, Stoke-on-Trent.**

University of Southampton. Department of Physics. Required immediately, **technician** (salary scale £315 × 15 – £450 and superannuation) according to experience and qualifications, to assist particularly with research work in the department. Knowledge of glass blowing and vacuum techniques advantageous. Written applications, giving full details of experience and qualifications together with names of two referees, should be sent as soon as possible to The Secretary and Registrar, The University, Southampton.

Development Engineers or **Physicists.** There are two vacancies in a rapidly expanding department of a light Engineering firm for work on aircraft and other specialized instruments.
(1) A minimum of five years industrial experience on small electro mechanical devices. Salary according to experience and qualifications ;
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